

**IN THE SPECIFICATION:**

Please replace paragraph [0017] with the following amended paragraph:

[0017] The present invention generally provides an electrochemical plating cell configured to plate metal onto semiconductor substrates using a small volume cell, *i.e.*, a cell with a volume that houses less than about 4 liters of electrolyte in the cell itself, preferably between about 1 and 3 liters, and potentially between about 2 and about 8 liters of electrolyte solution in an adjacent fluidly connected supply tank. These small volumes of fluid required to operate the cell of the invention allow the electroplating cell to be used for a predetermined range of substrates, *i.e.*, 100 - 200, and then the solution may be discarded and replaced with new solution. The electrochemical plating cell is generally configured to fluidly isolate an anode of the plating cell from a cathode or plating electrode of the plating cell via a cation membrane 112 positioned between the substrate being plated and the anode of the plating cell. Additionally, the plating cell of the invention is generally configured to provide a first fluid solution to an anode compartment, *i.e.*, the volume between the upper surface of the anode 105 and the lower surface of the membrane 112, and a second fluid solution (a plating solution) to the cathode compartment, *i.e.*, the volume of fluid positioned above the upper membrane surface. The anode 105 of the plating cell 100 generally includes a plurality of slots formed therein, the plurality of slots being positioned parallel to each other and are configured to remove a concentrated hydrodynamic Newtonian fluid layer from the anode chamber surface during plating processes. A membrane support assembly 106 having a plurality of slots or channels formed in a first side of the assembly, along with a plurality of bores formed into a second side of the membrane support assembly, wherein the plurality of bores are in fluid communication with the slots on the opposing side of the membrane support assembly.

Please replace paragraph [0020] with the following amended paragraph:

[0020] The membrane 112 generally operates to fluidly isolate the anode chamber from the cathode chamber of the plating cell. The membrane Membrane 112 is generally an ionic membrane. The ion exchange membrane generally includes fixed negatively charged groups, such as  $\text{SO}_3^-$ ,  $\text{COO}^-$ ,  $\text{HPO}_2^-$ ,  $\text{SeO}_3^-$ ,  $\text{PO}_3^{2-}$ , or other negatively charged groups amenable to plating processes. The membrane Membrane 112 allows a particular type of ions to travel through the membrane, while preventing another type of ion from traveling or passing through the membrane. More particularly, the membrane 112 may be a cationic membrane that is configured to allow positively charged copper ions ( $\text{Cu}^{2+}$ ) to pass therethrough, *i.e.*, to allow copper ions to travel from the anode in the anolyte solution through the membrane 112 into the catholyte solution, where the copper ions may then be plated onto the substrate. Further, the cationic membrane may be configured to prevent passage of negatively charged ions and electrically neutral species in the solution, such as the ions that make up the plating solution and catholyte additives. It is desirable to prevent these catholyte additives from traveling through the membrane 112 and contacting the anode, as the additives are known to break down upon contacting the anode. More particularly, membranes with negatively charged ion groups like  $\text{SO}_3^-$  etc. not only to facilitate Cu ions transport from the anolyte to the catholyte ~~catholyte~~, but also to prevent penetration of accelerators to anode. The accelerator is generally negatively charged organic ion:  $\text{SO}_3^-$ - $\text{C}_3\text{H}_6$ -S-S- $\text{C}_3\text{H}_6$ - $\text{SO}_3^-$ , so it can't penetrate into or through the cation membrane. This is important, as consumption of accelerators on copper anodes on conventional plating apparatuses without the ionic membrane is very high.

Please replace paragraph [0027] with the following amended paragraph:

[0027] Figure 2 illustrates a perspective view of base member 104. The upper surface of base member 104 generally includes an annular recess 201 configured to receive a disk shaped anode 105 in the recessed portion 201. Further, the surface of annular recessed portion 201 generally includes a plurality of channels 202 formed therein. Each of channels 202 are generally positioned in parallel orientation with each other and terminate at the periphery of recessed region 201. Additionally, the periphery

of recessed region 201 also includes an annular drain channel 203 that extends around the perimeter of recessed region 201. Each of the plurality of parallel positioned channels 202 terminate at opposing ends into annular drain channel 203. Therefore, channels 202 may receive dense fluids from anode channels slots 302 and transmit the dense fluids to a drain channel 203 via base channels 202. The vertical wall that defines recessed region 201 generally includes a plurality of slots 204 formed into the wall. The slots 204 are generally positioned in parallel orientation with each other, and further, are generally positioned in parallel orientation with the plurality of channels 202 formed into the lower surface of recessed region 201. Base member 104 also includes at least one fluid supply conduit 205 configured to dispense a fluid into the anode region of plating cell 100, along with at least one plating solution supply conduit 206 that is configured to dispense a plating solution into the cathode compartment of plating cell 100. The respective supply conduits 205 and 206 are generally in fluid communication with at least one fluid supply line 109 positioned on a lower surface of base member 104, as illustrated in Figure 1. Base member 104 generally includes a plurality of conduits formed therethrough (not shown), wherein the conduits are configured to direct fluids received by individual fluid supply lines 109 to the respective cathode and anode chambers of plating cell 100.

Please replace paragraph [0028] with the following amended paragraph:

[0028] Figure 3 illustrates a perspective view of base member 104 having the disk shaped anode 105 positioned therein. Anode 105, which is generally a disk shaped copper member, *i.e.*, a soluble-type copper anode generally used to support copper electrochemical plating operations, generally includes a plurality of slots 302 formed therein. The slots 302 generally extend through the interior of anode ~~302~~ 105 and are in fluid communication with both the upper surface and lower surface of anode 105. As such, slots 302 allow fluids to travel through the interior of anode 105 from the upper surface to the lower surface. Slots 302 are positioned in parallel orientation with each other. However, when anode 105 is positioned within annular recess 201 of base member 104, the parallel slots 302 of anode 105 are generally positioned orthogonal to both slots 204 and channels 202 of base member 104, as illustrated cooperatively by

Figures 2 and 3. Additionally, slots 302 generally do not continuously extend across the upper surface of anode 105. Rather, slots 302 are broken into a longer segment 303 and a shorter segment 304, with a space 305 between the two segments, which operates to generate a longer current path through anode 105 from one side to the other. Further, adjacently positioned slots 302 have the space 305 positioned on opposite sides of the anode upper surface. The current path from the lower side of anode to the upper side of anode generally includes a back and forth type path between the respective ~~channels~~ slots 302 through the spaces 305. Further, the positioning of spaces 305 and ~~channels~~ slots 302 provides for improved concentrated Newtonian fluid removal from the surface of the anode 105, as the positioning of ~~channels~~ slots 302 provides a shortest possible distance of travel for the dense fluids to be received in ~~channels~~ slots 302. This feature is important, as dense fluids generally travel slowly, and therefore, it is desirable.

Please replace paragraph [0031] with the following amended paragraph:

[0031] Assuming a tilted implementation is utilized, a substrate is first immersed into a plating solution contained within inner basin 102. Once the substrate is immersed in the plating solution, which generally contains copper sulfate, chlorine, and one or more of a plurality of organic plating additives (levelers, suppressors, accelerators, etc.) configured to control plating parameters, an electrical plating bias is applied between a seed layer on the substrate and the anode 105 positioned in a lower portion of plating cell 100. The electrical plating bias generally operates to cause metal ions in the plating solution to deposit on the cathodic substrate surface. The plating solution supplied to inner basin 102 is continually circulated through inner basin 102 via fluid inlet/outlets 109. More particularly, the plating solution may be introduced in plating cell 100 via a fluid inlet 109. The solution may travel across the lower surface of base member 104 and upward through one of ~~fluid apertures~~ plating solution supply conduits 206. The plating solution may then be introduced into the cathode chamber via a channel formed into plating cell 100 that communicates with the cathode chamber at a point above membrane support 106. Similarly, the plating solution may be removed from the cathode chamber via a fluid drain positioned above membrane support 106, where the

fluid drain is in fluid communication with one of fluid drains 109 positioned on the lower surface of base member 104. For example, base member 104 may include first and second ~~fluid apertures~~ plating solution supply conduits 206 positioned on opposite sides of base member 404 104. The oppositely positioned ~~fluid apertures~~ plating solution supply conduits 206 may operate to individually introduce and drain the plating solution from the cathode chamber in a predetermined direction, which also allows for flow direction control. The flow control direction provides control over removal of light fluids at the lower membrane surface, removal of bubbles from the anode chamber, and assists in the removal of dense or heavy fluids from the anode surface via the channels 202 formed into base 104.

Please replace paragraph [0032] with the following amended paragraph:

[0032] Once the plating solution is introduced into the cathode chamber, the plating solution travels upward through diffusion plate 110. Diffusion plate 110, which is generally a ceramic or other porous disk shaped member, generally operates as a fluid flow restrictor to even out the flow pattern across the surface of the substrate. Further, the diffusion plate 110 operates to resistively damp electrical variations in the electrochemically active area the anode or cation membrane surface, which is known to reduce plating uniformities. Additionally, embodiments of the invention contemplate that the ceramic diffusion plate 110 may be replaced by a hydrophilic plastic member, *i.e.*, a treated PE member, a PVDF member, a PP member, or other material that is known to be porous and provide the electrically resistive damping characteristics provided by ceramics. However, the plating solution introduced into the cathode chamber, which is generally a plating catholyte solution, *i.e.*, a plating solution with additives, is not permitted to travel downward through the membrane (not shown) positioned on the lower surface 404 (*i.e.*, membrane engaging surface 404) of membrane support assembly 106 into the anode chamber, as the anode chamber is fluidly isolated from the cathode chamber by the membrane. The anode chamber includes separate individual fluid supply and drain sources configured to supply an anolyte solution to the anode chamber. The solution supplied to the anode chamber, which may generally be copper sulfate in a copper electrochemical plating system, circulates exclusively through the

anode chamber and does not diffuse or otherwise travel into the cathode chamber, as the membrane positioned on membrane support assembly 106 is not fluid permeable in either direction.

Please replace paragraph [0033] with the following amended paragraph:

[0033] Additionally, the flow of the fluid solution (anolyte, *i.e.*, a plating solution without additives, which may be referred to as a virgin solution) into the anode chamber is directionally controlled in order to maximize plating parameters. For example, anolyte may be communicated to the anode chamber via an individual fluid inlet 109. Fluid inlet 109 is in fluid communication with a fluid channel formed into a lower portion of base member 104 and the fluid channel communicates the anolyte to one of ~~apertures~~ fluid supply conduits 205. A seal positioned radially outward of ~~apertures~~ fluid supply conduits 205, in conjunction with the surrounding structure, directs the anolyte flowing out of ~~apertures~~ fluid supply conduits 205 upward and into slots 204. Thereafter, the anolyte generally travels across the upper surface of the anode 105 towards the opposing side of base member 104, which in a tilted configuration, is generally the higher side of plating cell 100. The anolyte travels across the surface of the anode below the membrane positioned immediately above. Once the anolyte reaches the opposing side of anode 105, it is received into a corresponding fluid channel and drained from plating cell 100 for recirculation.

Please replace paragraph [0034] with the following amended paragraph:

[0034] During plating operations, the application of the electrical plating bias between the anode and the cathode generally causes a breakdown of the anolyte solution contained within the anode chamber. More particularly, the application of the plating bias operates to generate multiple hydrodynamic or Newtonian layers of the copper sulfate solution within the anode chamber. The hydrodynamic layers generally include a layer of concentrated copper sulfate positioned proximate the anode, an intermediate layer of normal copper sulfate, and a top layer of lighter and depleted copper sulfate proximate the membrane. The depleted layer is generally a less dense and lighter layer of copper sulfate than the copper sulfate originally supplied to the

anode compartment, while the concentrated layer is generally a heavier and denser layer of copper sulfate having a very viscous consistency. The dense consistency of the concentrated layer proximate the anode causes electrical conductivity problems (known as anode passivation) in anodes formed without slots 302. However, slots 302, in conjunction with the tilted orientation of plating cell 100, operate to receive the concentrated viscous layer of copper sulfate and remove the layer from the surface of the anode, which eliminates conductivity variances. Further, plating cell 100 generally includes one side that is tilted upward or vertically positioned above the other side, and therefore, the surface of anode 105 is generally a plane that is also tilted. The tilt causes the layer of concentrated copper sulfate generated at the surface of the anode 105 to generally flow downhill as a result of the gravitational force acting thereon. As the concentrated copper sulfate layer flows downhill, it is received within one of channels 302 and removed from the surface of the anode 105. As discussed above, ~~channels~~ slots 302 are generally parallel to each other and are orthogonal to ~~channels~~ the slots 204. Therefore, channels 302 are also orthogonal to channels 202 and formed into the lower surface of base member 104. As such, each of slots 302 ~~or finally~~ intersect several of channels 202. This configuration allows the concentrated copper sulfate received within slots 302 to be communicated to one or more of channels 202. Thereafter, the concentrated copper sulfate may be communicated via channels 202 to the annular drain channel 203 positioned within recessed region 201. The drain 203 in communication with channels 202 may generally be communicated through base plate 104 and back to a central anolyte supply tank, where the concentrated copper sulfate removed from the anode surface may be recombined with a volume of stored copper sulfate used for the anolyte solution.